Notes on earthquakes.—May 15, 4:27 p. m., very slight shock; May 22, 9:19 p. m., tremors. In connection with the Martinique disaster, it may be noted that on the 11th and 12th especially, and on many other days afterwards, sunrise was accompanied by unusual red and purplish tints, which were noticed not only at San Jose, but also at several other places on the Atlantic slope.

THE WINDS AND RAINFALL OF NEW HAVEN.

By T. H. DAVIS, New Haven, Conn.

THE FREQUENCY OF WIND DIRECTION AS OBSERVED AT THE LOCAL WEATHER BUREAU OFFICE SINCE ITS INSTALLATION IN 1873.

The general circulatory system of the atmosphere is subject to laws that must be discovered by the discussion of continuous observations. This is particularly true of the great equatorial currents which flow away from the equator in the higher strata of the atmosphere, and the corresponding great polar currents flowing from the poles toward the equator in the lower atmosphere. These currents do not travel in direct paths parallel to the lines of longitude, as might at first be supposed, but being perfectly free, the masses of air in motion are subject to the effect of the rotation of the earth on its axis, which causes a deflection of their direction to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

These fundamental currents do not follow continuous courses, but the joint result is the production of what are known as the "prevailing westerlies" near the parallels of forty degrees north and south at the earth's surface.

At southern stations in the United States and about the Gulf of Mexico the prevalent winds have easterly components because of their close proximity to the northeasterly trades.

Cyclonic storms which cross this continent in an easterly or northeasterly direction cause occasional winds of greater or less intensity over districts through which they pass, and these may blow from any point of the compass, depending upon whether the storm center passes through, or north or south of the place of observation. These are factors of more or less importance in determining the prevailing wind direction at any point. Each is more marked in some seasons and in some years than in others, and helps to account for the irregular oscillations of the winds.

If we would embrace all influences liable either individually or collectively to interfere with the general circulation over New Haven, it would be proper to note that its location is as follows:

(1) About 400 miles from the northern edge of the calms of the Tropic of Cancer; (2) in the region of prevailing westerlies; (3) about 300 miles northwest from the average path of the centers of West Indian hurricanes; (4) about 150 miles from the landward margin of the Gulf stream; (5) open to Long Island Sound from southeast to south-southwest; (6) subject to the effects of the Arctic current which is said to flow between the landward margin of the Gulf stream and Long Island Sound.

Any or all of these circumstances may exert a more or less marked interference with the winds that would normally prevail at this point.

The topography of the surrounding country is also a factor in disturbing the wind direction. Winds that blow toward New Haven from the west, north, or northeast meet the Allegheny Mountains of Pennsylvania, the Green Mountains of Vermont, or the White Mountains of New Hampshire, respectively, besides other minor elevations. These rugged eminences, together with their extensive valleys, in considerable measure become deflecting influences on the wind's direction. Insolation and terrestrial radiation also exert influences by producing vertical currents, and these in their turn will materially affect the direction.

Since New Haven is on the coast, winds coming to it from the east, south, or southwest meet with scarcely any obstruction, the only interference being such as is experienced in their passage over the open ocean and the comparatively low-lying land.

The deflecting effects of the topographical character of the country in this vicinity are necessarily very small, but they may possibly be helpful in the explanation of the oscillations of frequency of direction.

One of the important factors to be considered in the investigation of the resultant wind direction for New Haven is its close proximity to the open ocean, by reason of which marked land and sea breezes are developed. These are particularly noticeable during the summer months. On summer mornings and evenings when the general atmosphere is free from observable motion there are distinct movements of large masses of air near the earth, from the land to the sea and from the sea to the land, respectively.

Taking all these points into consideration it will be readily perceived that we do not receive the true winds of the general circulation of the atmosphere, but are favored with resultants due to modifying influences. The directions of wind as observed by Weather Bureau officials at New Haven from 1873 to 1900, inclusive, are shown in Table 1, which gives for each year the percentages of wind frequency for each of the eight points of the compass, the percentage of calms, and finally the resultant directions for each year.[1]

TABLE 1.—*Wind directions in percentages, and annual resultants.*

Year.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Resultant direction.
										°
1873	16.7	11.2	2.2	5.5	10.4	14.5	9.0	20.0	10.4	w. 36 n.
1874	16.4	11.2	2.5	3.8	13.4	16.7	10.7	14.8	10.4	w. 18 n.
1875	20.0	15.0	3.6	4.1	13.4	14.8	10.7	14.8	3.6	w. 43 n.
1876	15.9	12.9	2.5	5.2	13.1	17.0	9.3	19.2	5.2	w. 26 n.
1877	17.8	15.1	3.6	3.8	10.4	20.0	6.3	15.6	7.4	w. 40 n.
1878	14.8	13.4	3.3	4.7	13.4	15.3	12.9	16.7	5.5	w. 24 n.
1879	16.4	12.6	2.7	4.1	12.9	18.1	8.5	19.7	4.9	w. 28 n.
1880	17.5	11.0	2.5	5.7	17.3	14.8	12.3	15.9	3.3	w. 14 n.
1881	18.9	15.6	1.9	6.0	13.7	15.1	9.3	12.9	6.6	w. 42 n.
1882	18.4	14.2	1.9	6.3	12.9	16.2	10.1	15.1	4.9	w. 33 n.
1883	18.4	13.4	3.0	6.3	13.1	17.3	9.0	15.6	3.8	w. 31 n.
1884	18.1	12.0	2.7	5.5	12.9	18.1	11.0	14.5	5.5	w. 20 n.
1885	19.7	10.7	3.3	3.8	14.8	14.2	14.0	12.6	6.8	w. 9 n.
1886	12.3	17.0	3.3	6.3	14.5	12.9	13.4	14.0	6.3	w. 26 n.
1887	16.2	12.6	3.8	6.3	14.8	14.2	13.1	15.1	3.8	w. 21 n.
1888	17.5	12.3	3.0	5.7	11.5	15.6	11.8	18.9	3.3	w. 32 n.
1889	11.8	17.0	4.4	5.7	13.4	15.3	13.0	17.3	2.2	w. 27 n.
1890	12.0	15.1	4.1	4.7	13.0	14.0	11.8	19.7	5.7	w. 31 n.
1891	14.2	14.8	3.8	6.6	12.9	18.9	12.0	15.9	1.0	w. 27 n.
1892	15.1	14.5	1.9	6.8	9.9	14.8	18.1	17.0	1.9	w. 28 n.
1893	21.0	17.8	3.6	6.8	7.9	17.3	12.0	13.4	.3	w. 55 n.
1894	21.0	15.1	4.7	5.2	9.6	19.7	12.3	11.8	1.0	w. 38 n.
1895	24.0	7.1	4.1	8.2	14.5	15.1	13.4	13.7	.0	w. 22 n.
1896	24.4	8.5	5.2	4.4	12.6	18.1	12.3	14.5	.3	w. 30 n.
1897	21.6	12.9	2.5	6.8	10.1	17.5	14.2	14.0	.3	w. 33 n.
1898	22.0	15.3	5.5	6.3	13.4	14.5	12.3	10.4	.3	w. 53 n.
1899	18.4	15.9	3.5	5.2	9.9	19.2	9.9	17.2	.8	w. 50 n.
1900	20.0	14.8	4.4	4.1	8.2	19.5	12.6	16.4	.0	w. 41 n.
Mean	17.9	13.6	3.4	5.5	12.4	16.4	11.6	15.4	3.8	w. 31 n.

Table 2 shows the mean percentage of winds from each of the eight points of the compass and the resultant directions for each month of the year.

The components of direction are exhibited graphically in figs. 1 to 4, and the resultant directions in figs. 5 and 6. In fig. 7 are shown resultant directions for the four seasons.

These curves show very clearly the march of the various winds during the year. From fig. 1 we see that the south winds have a maximum frequency in July and a minimum in

[1] From August 25, 1872, to October 31, 1879, observations were made at 7:35 a. m., 4:35 and 11:35 p. m., Washington time; from November 1, 1879, to December 31, 1884, at 7 a. m., 3 and 11 p. m., Washington time; January 1, 1885, to December 31, 1886, at 7 a. m., 3 and 11 p. m., seventy-fifth meridian time; January 1, 1887 to June 30, 1888, at 7 a. m., 3 and 10 p. m., seventy-fifth meridian time; July 1, 1888, to date, at 8 a. m. and 8 p. m. seventy-fifth meridian time. The resultant directions in Tables 1 and 2 are based on observations of wind direction only, and do not take into account variations in the average velocity for different directions.—ED.

December, while the north winds have their maximum in January and their minimum in June. The seasonal fluctuations are much more marked in the south than in the north winds.

TABLE 2.—*Wind directions in percentages, and monthly resultants.*

Months.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Resultant direction.
										°
January.....	21.94	15.81	1.61	1.94	5.17	14.51	16.78	18.71	3.55	w. 49 n.
February....	20.00	15.00	2.50	3.57	6.43	12.85	13.58	20.00	6.07	w. 53 n.
March.....	20.33	13.55	3.88	4.84	9.68	11.62	11.62	20.65	3.83	w. 55 n.
April.....	17.33	15.33	4.00	8.33	13.33	11.33	9.66	17.33	3.36	w. 54 n.
May.....	12.90	13.22	5.17	11.94	20.33	15.16	7.10	10.33	3.85	w. 72 s.
June.....	12.00	9.00	4.66	10.00	22.00	19.33	7.33	11.33	4.35	w. 56 s.
July.....	13.87	8.39	3.23	5.81	22.27	22.27	7.42	12.59	4.15	w. 35 s.
August.....	15.81	12.90	3.23	6.45	18.07	19.04	8.39	11.29	4.82	w. 15 s.
September...	16.66	15.33	4.00	5.33	14.00	18.66	8.33	13.66	4.03	w. 26 n.
October.....	19.68	14.51	3.23	4.20	8.71	16.78	12.26	17.10	3.53	w. 42 n.
November...	20.33	13.33	2.33	2.66	6.99	15.00	18.33	17.66	3.37	w. 40 n.
December....	21.62	14.51	0.65	1.61	4.84	17.42	17.74	17.42	4.19	w. 40 n.

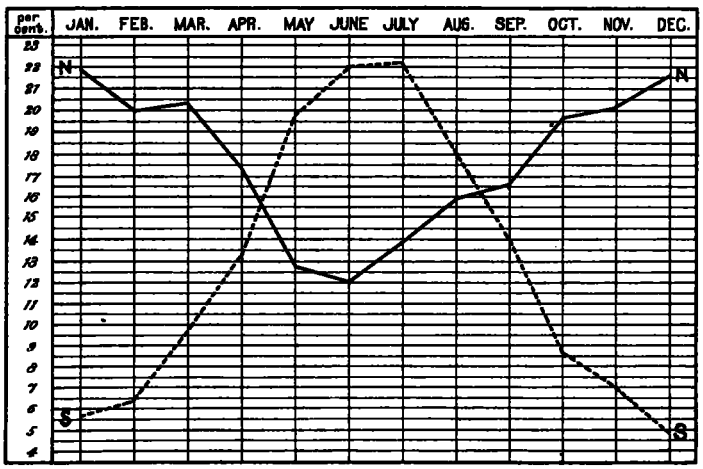

FIG. 1.—Percentage curve of north and south winds, from Table 2.

The curves shown in fig. 2 are not so regular in character as those in fig. 1. The southwest winds have a decided maximum in July and a minimum in April and the northeast winds a minimum in June and July with only slight variations during the remaining months of the year.

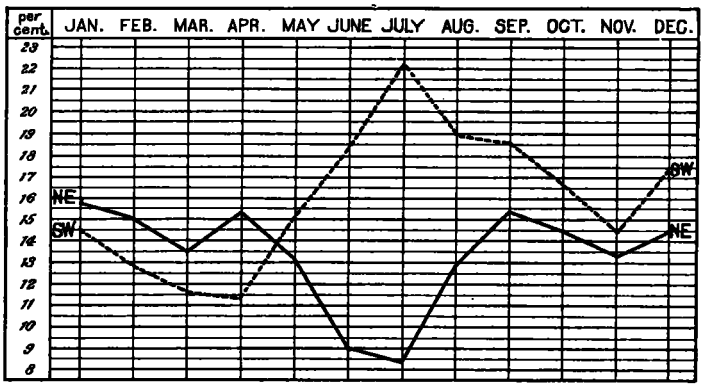

FIG. 2.—Percentage curves of northeast and southwest winds, from Table 2.

Fig. 3 shows a low percentage of east winds throughout the year. West winds are frequent from November to January and comparatively few from May to September; while northwest winds, as shown by fig. 4, are frequent from October to April and few from May to August. Southeast winds show a decided maximum in May.

The striking feature of these curves is the increased frequency of southerly winds and the decreased frequency of north and west winds during the summer season. This is partly due to monsoon influences, but no doubt the land and sea breezes have an important effect.

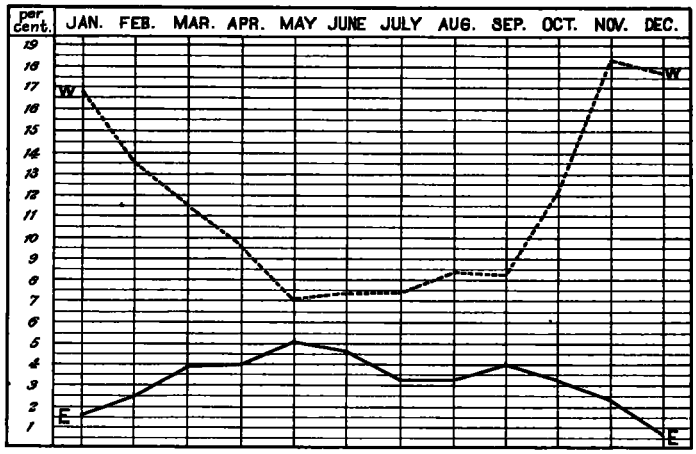

FIG. 3.—Percentage curve of east and west winds, from Table 2.

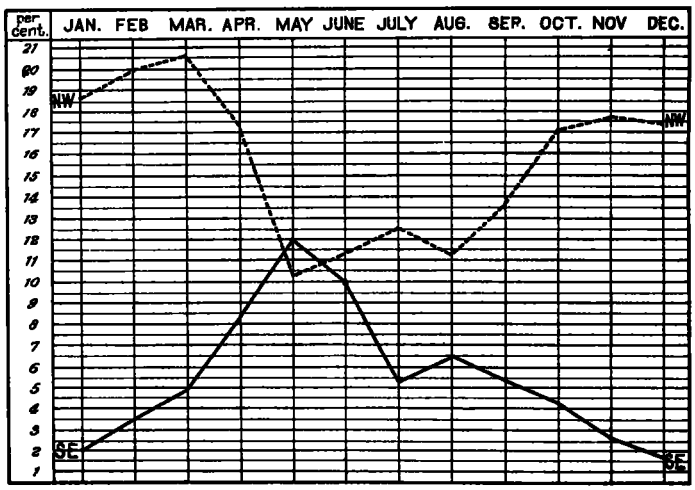

FIG. 4.—Percentage curve of southeast and northeast winds, from Table 2.

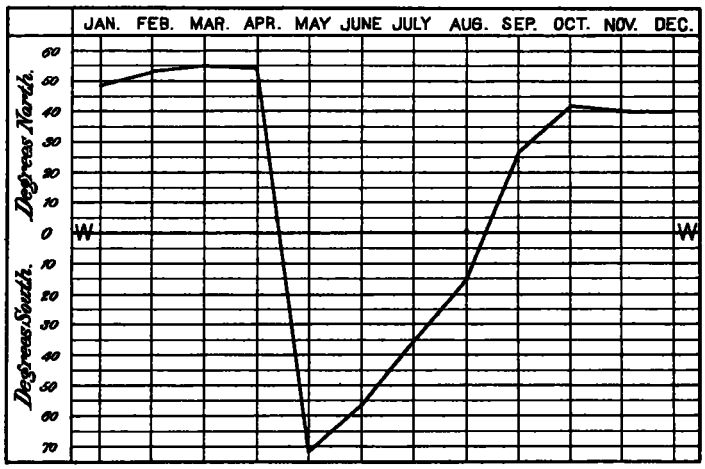

FIG. 5.—Monthly resultant directions, 28-year averages, from Table 2.

PRECIPITATION AT NEW HAVEN, CONN., FOR TWENTY-EIGHT YEARS, 1873–1900.

Precipitation in whatever form it may be deposited upon the surface of the earth appears to be the most erratic and variable quantity with which we have to deal in the discussion of

meteorological phenomena. The rainfall for New Haven, as shown by the measurements taken at the local United States Weather Bureau is apparently almost entirely dependent upon passing storms. There are no high mountains to produce the abundant precipitation that occurs in some other districts, and proximity to the ocean does not appreciably increase its rainfall, since so large a percentage of the winds are from the west or north. The discomfort occasioned by high humidity, fogs, and mists is, however, very generally attributed to its marine position.

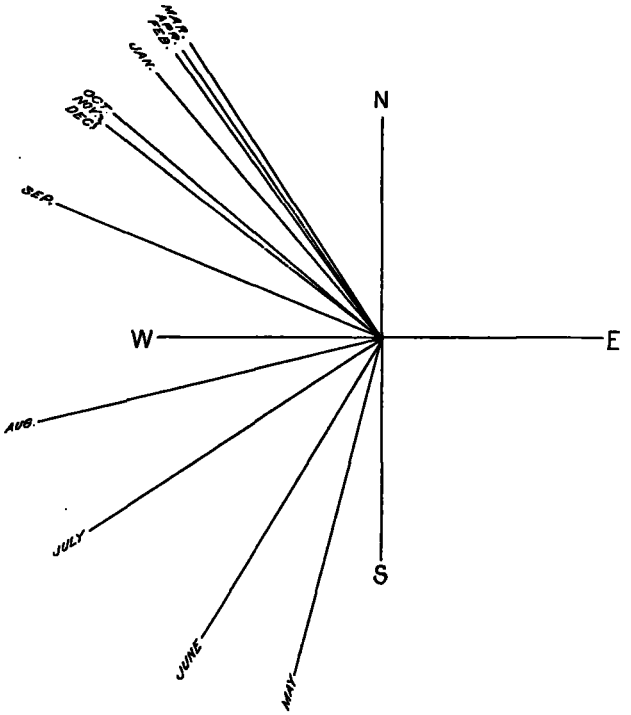

FIG. 6.—Average resultant direction for each month.

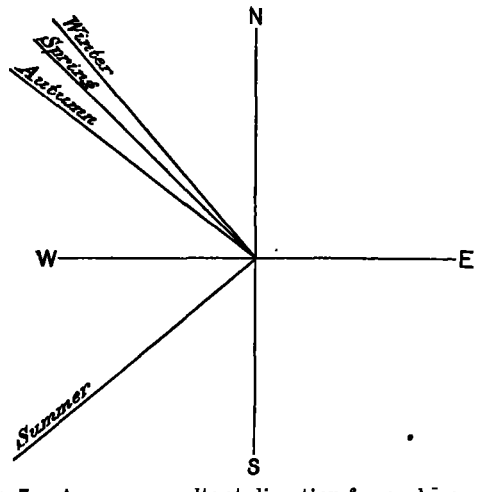

FIG. 7.—Average resultant direction for each season.

As a rule the cyclonic storms that develop in the northwestern part of the United States cross this country in an easterly direction, passing out to sea through the St. Lawrence Valley; they usually bring rain to New Haven. Another class of storms originates in the southwest. They travel in a northeasterly direction and pass out to sea at a point between Cape Hatteras and northern Maine; of these a goodly proportion pass over or near New Haven, producing abundant rains. We also receive a very fair share of rainfall from the so-called West Indian storms.

In addition to the precipitation accompanying these storm areas we are favored with frequent heavy showers of rain during the hot summer months, which approach this point from the northwest or the southwest, and are usually accompanied by the well known thunderstorm phenomena. This no doubt accounts for the fact that on the average for twenty-eight years July proves to be the wettest month of the year in New Haven.

The annual average rainfall recorded at New Haven is 47.38 inches. It is quite possible that the actual rainfall is in excess of this amount by from 5 to 10 per cent, since it has been shown by long series of observations that a rain gage at a high elevation generally collects less rainfall than one placed on the ground. For this reason, Prof. Alfred J. Henry, in his excellent memoir on the "Rainfall of the United States,"[1] informs us that:

> In general it does not seem possible to avoid the conclusion that the absolute amount of precipitation, as registered by the Weather Bureau gages, falls short of the true amount by quantities varying from 5 to 10 per cent of the annual.

The rain gage used in the observations at New Haven is provided with a funnel 8 inches in diameter and the elevation of the top rim of this funnel is 110 feet above ground or about 140 feet above mean sea level. The observer informs me that it has not been moved from its present position on the roof of the building where the local Weather Bureau is situated since its installation in 1873; therefore, the results are eminently reliable for that particular spot.

Table 3 gives a complete record of the amount of rain, measured in inches and hundredths, for each month; the totals for each year of the 28-year period under consideration; the departures from the normal; and the average for the period elapsing since 1872. This latter shows the necessity of a long period of observations before the adoption of a mean. At the bottom of the table are given the means for each month for the entire period, which show that, on the average, July is the wettest month and June the driest.

TABLE 3.—*Monthly, annual, and average precipitation.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total annual.	Average.	Departure from normal.
1873...	7.42	3.45	4.01	4.95	6.27	2.07	1.55	9.90	2.12	6.18	4.73	4.41	57.06	57.06	+ 9.68
1874...	4.29	3.87	1.34	7.89	4.92	3.41	4.90	12.99	4.07	1.86	3.44	2.85	55.82	56.44	+ 8.44
1875...	2.72	3.98	3.24	3.28	2.71	3.50	4.42	5.56	2.10	3.18	7.44	1.39	43.52	52.13	− 3.86
1876...	1.54	4.29	10.15	7.63	3.12	1.86	11.05	1.20	5.34	1.12	4.43	2.38	54.11	52.63	+ 6.73
1877...	2.60	1.07	8.09	3.44	2.14	6.17	2.37	5.69	1.13	10.09	7.11	1.46	51.36	52.37	+ 3.98
1878...	6.80	6.40	4.18	5.08	3.75	2.62	2.53	4.93	7.67	2.33	6.33	5.50	58.12	53.33	+10.74
1879...	2.69	3.89	5.82	6.08	3.22	4.62	9.50	9.40	2.13	1.41	2.33	4.41	55.50	53.64	+ 8.12
1880...	3.75	3.80	5.68	3.69	1.24	1.21	4.90	8.14	3.73	4..7	2.82	3.49	46.52	52.75	− 0.86
1881...	4.79	6.17	10.42	1.71	3.89	5.14	3.53	2.51	1.45	2.78	4.18	4.75	51.32	52.59	+ 3.94
1882...	5.91	4.52	3.59	1.55	5.05	2.74	3.03	0.26	13.43	3.54	1.31	2.99	47.92	52.12	+ 0.54
1883...	3.60	5.00	1.64	2.23	4.52	1.83	5.67	1.26	2.43	5.87	1.56	3.85	39.46	50.98	− 7.92
1884...	4.63	5.57	4.15	2.36	3.32	5.26	5.89	5.60	1.41	2.49	2.24	6.41	49.33	50.84	+ 1.95
1885...	4.05	3.15	1.19	2.31	2.61	1.43	2.51	8.13	0.77	5.37	3.49	3.31	38.82	49.87	− 9.06
1886...	3.53	5.95	3.20	3.21	2.74	2.84	4.69	4.56	2.35	1.95	3.83	3.47	42.32	49.33	− 5.06
1887...	4.24	6.22	4.22	2.75	0.18	5.62	4.66	4.80	2.21	3.24	2.85	3.09	44.08	48.98	− 3.30
1888...	5.48	3.16	7.46	2.57	6.03	2.15	1.76	7.10	7.68	6.46	4.73	5.68	60.26	49.69	+12.88
1889...	4.47	2.08	1.44	4.01	3.81	3.17	17.08	4.38	4.98	3.96	7.78	2.62	59.78	50.28	+12.40
1890...	3.07	3.19	6.60	2.89	4.24	3.12	6.59	2.67	5.38	7.63	0.67	2.90	48.95	50.21	+ 1.57
1891...	6.77	5.88	3.68	2.35	1.92	1.90	4.52	3.14	3.96	4.62	2.21	3.74	44.69	49.92	− 2.69
1892...	5.39	1.56	3.07	1.31	5.11	2.36	4.33	4.99	1.54	0.94	5.46	1.72	37.78	49.31	− 9.60
1893...	3.47	6.23	4.50	3.84	7.08	2.07	1.89	4.86	2.24	4.75	2.56	3.22	46.71	49.19	− 0.67
1894...	2.74	4.23	1.15	2.24	4.49	0.49	2.40	1.70	4.63	6.11	4.23	3.33	37.74	48.67	− 9.64
1895...	5.13	0.99	2.36	3.11	1.70	2.41	3.77	3.91	2.51	3.32	4.84	1.91	35.96	48.11	−11.42
1896...	1.82	5.65	5.61	1.19	3.67	2.96	3.86	2.57	3.42	2.91	2.33	2.40	38.39	47.71	− 8.99
1897...	3.85	2.00	3.66	2.44	5.03	2.47	16.63	6.81	2.42	1.25	5.72	5.61	57.89	48.12	+10.51
1898...	4.96	4.55	2.54	4.43	8.03	0.21	5.03	6.65	2.30	7.22	5.69	2.11	53.72	48.33	+ 6.34
1899...	4.33	3.39	7.28	1.79	2.52	2.59	4.17	0.65	3.33	1.78	1.89	1.56	35.28	47.85	−12.10
1900...	3.60	6.39	4.21	1.95	3.30	1.79	2.28	0.90	2.10	2.03	4.14	2.14	34.83	47.38	−12.55
Means	4.20	4.17	4.44	3.30	3.81	2.79	5.19	4.83	3.53	3.87	3.94	3.31	47.38		

Some precipitation was recorded during every month of the entire twenty-eight years, the nearest approach to zero being 0.18 inch in May 1887. On a few other occasions the precipitation was considerably below one inch, viz:

August, 1882, 0.26 inch; September, 1885, 0.77 inch; November, 1890, 0.67; June, 1894, 0.49 inch; June, 1898, 0.21 inch.

[1] Weather Bureau Bulletin D, p. 9.

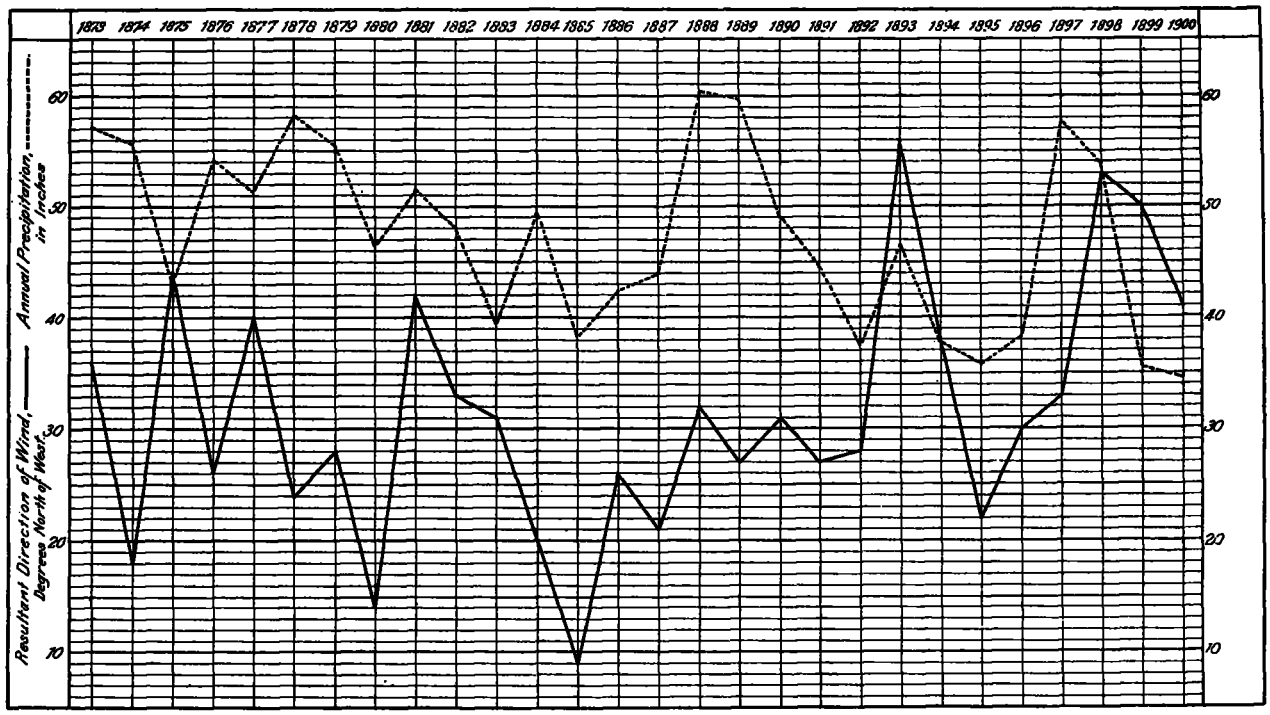

FIG. 8.—Annual precipitation and resultant direction of all winds observed at New Haven, Conn.

On the other hand the maximum falls for any month were as follows:

August, 1874, 12.99 inches; March, 1876, 10.15 inches; July, 1876, 11.05 inches; October, 1877, 10.09 inches; March, 1881; 10.42 inches; September, 1882, 13.43 inches; July, 1889, 17.08 inches; July, 1897, 16.63 inches.

The total amount of precipitation for the entire twenty-eight years was 1,326.74 inches, and the percentages for each month during this period were as follows:

January, 8.87; February, 8.79; March, 9.38; April, 6.96; May, 8.03; June, 5.88; July, 10.97; August, 10.19; September, 7.45; October, 8.18; November, 8.33; December, 6.98.

Adopting a seasonal division we have for twenty-eight years—

Season.	Total.	Percentage.	Average.
	Inches.		*Inches.*
Spring months	323.37	24.37	11.55
Summer months	358.78	27.04	12.81
Autumn months	317.63	23.94	11.34
Winter months	326.96	24.65	11.68
Year	1,326.74	100.00	47.38

It will be observed that for New Haven the summer months show greater precipitation than any other part of the year.

In fig. 8, I have plotted the rainfall for each year from 1873 to 1900 to ascertain if there is a periodicity in the fluctuations of the amount. The resulting curve does not establish any such periodicity. Comparing it with the resultant curve for wind direction at New Haven in the same figure, it will be noted that there appears to be only a slight relation between the two. This is a subject for further investigation, however.

EARLY RAINFALL RECORDS.

During the writing of this paper, Prof. Willis L. Moore, Chief of the Weather Bureau, very courteously supplied me with a copy of records of precipitation at New Haven for a continuous period of eighteen years (with the exception of August 1805), commencing nearly one hundred years ago, viz: 1804–1821. These interesting records are shown in Table 4.[3]

TABLE 4.—*Monthly and annual precipitation, 1804–1821.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total annual.
1804	4.76	2.28	4.12	3.60	3.07	2.30	3.32	1.85	4.90	6.07	3.21	4.32	43.30
1805	6.93	1.95	2.20	2.65	3.92	2.71	0.86	3.88*	1.65	6.75	3.20	4.10	*40.80
1806	3.20	1.87	1.67	2.90	1.82	1.50	3.60	6.80	5.60	0.70	6.15	2.80	38.61
1807	3.80	7.80	3.90	4.75	5.00	2.43	4.32	5.00	1.32	1.45	1.45	4.10	45.32
1808	4.38	2.85	2.70	2.95	9.35	4.08	8.55	0.73	4.37	2.94	2.00	4.50	49.40
1809	4.70	3.14	2.42	3.58	2.23	4.34	4.81	4.38	0.14	5.12	2.39	7.30	44.55
1810	1.46	1.22	2.89	2.67	1.31	4.17	6.88	5.35	1.55	2.03	8.34	1.53	39.40
1811	3.32	5.01	3.69	2.73	1.83	1.89	6.24	5.30	1.88	5.44	4.37	5.96	47.66
1812	4.66	4.28	1.03	3.32	3.51	3.42	4.19	5.55	3.51	4.45	3.03	3.22	44.17
1813	4.54	1.38	5.36	3.68	7.33	4.17	4.04	4.11	4.92	5.86	3.91	4.10	53.40
1814	1.60	7.65	3.71	3.82	6.20	3.00	7.03	9.13	3.22	1.23	7.72	1.75	56.06
1815	3.09	3.33	5.27	3.07	3.87	3.88	6.94	4.90	9.79	0.68	2.19	3.63	50.64
1816	3.68	5.45	2.46	2.72	2.81	3.67	1.15	1.61	6.65	4.14	2.81	0.85	38.00
1817	2.59	4.87	3.27	2.80	1.30	8.90	2.46	4.27	2.74	1.15	5.39	3.64	43.38
1818	2.90	2.30	4.00	4.67	6.36	2.49	3.05	1.63	5.79	1.22	1.53	2.08	38.02
1819	1.16	5.16	5.60	3.94	4.31	1.91	1.44	2.65	3.46	1.26	0.65	2.35	33.89
1820	3.15	3.87	5.36	0.86	5.97	0.96	6.23	2.34	2.22	8.80	3.00	3.43	46.19
1821	4.49	5.28	2.32	4.70	3.44	4.60	1.71	1.00	4.74	5.11	4.28	2.97	44.64
Means.	3.58	3.86	3.44	3.30	4.09	3.36	4.27	3.89	3.80	3.58	3.64	3.49	44.30

*The record for August, 1805, is missing. I have inserted for this month the mean for the period.

For this period the average annual precipitation is only 44.30 inches, which is 3.08 inches less than the mean derived from the observations for 1873–1900. The extremes of precipitation are less marked than in the recent period, the greatest monthly amount being 9.79 inches in September, 1815, and the lowest 0.65 inch in November, 1819.

These records were taken at an elevation of 45 feet, nearly 100 feet nearer mean sea level than those of the 28-year period. If we grant that the rain gage used and the methods of measurement were as correct as at the present time, it appears that the precipitation in the early part of the last century was less than now, but had much the same character.

[3] This table is a part of the series, 1804–1829, by Professors Loomis, Olmstead, and others, the means for which are given in Schott's Precipitation Tables, 1872. From 1822–1829, inclusive, the records for many months are missing.—Ed.